An Evaluation of HF Modem Performance

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Abstract

High Frequency (HF) skywave communications have long been employed for 3 kHz voiceband channel. The ionospheric medium is well-known for its time-varying effects in which the propagating signal must contend with distortion, noise and interference. With the development of advanced digital signal processing (DSP) technology, the reliability and data transfer rate have been increased through the use of modern HF data modems. In equatorial regions, the characteristics of the ionospheric medium are very subtle and complex leading to the degradation in the performance of HF communication systems. To optimise system performance, particularly of HF modems, the channel characteristics must be investigated. However, the ionospheric characteristics at low latitudes are often unknown or only exist in very limited databases and for certain geographical locations.

The subject of this thesis is an evaluation of HF modem performance in equatorial regions based on experimental data. A bit error rate (BER) performance estimation method based on the channel scattering functions (CSFs) at vertical-incidence (VI) is proposed. The proposed CSF-based BER Estimation Method (BEREM) is developed using a collection of CSFs obtained in Thailand (lat 12.70°N, lon 100.65°E). At this location, the variability of the ionosphere is affected significantly by the presence of the magnetic equator which is approximately at 9°N geographical latitude. The CSF data are obtained and used for channel characterisation and simulation. The proposed BER estimation technique was validated using the results from on-air HF modem trials conducted on a 612-km skywave path across the Gulf of Thailand where the geomagnetic equator situates just south of the reflection point of propagation.

The major component of this study, which forms the CSF-based BER estimation technique, involves the characterisation of the 612-km skywave path based on VI Doppler ionograms. An investigation is undertaken on the implementation of the equivalent frequency transformation (or also known as the range-conversion technique) from VI to oblique-incidence (OI) ionograms, assuming stationarity of the ionosphere over 15-minute period and over a 306-km radius from the VI sounding system. The study also focuses on the equivalent Doppler frequency transformation (range-conversion for Doppler frequency) in order to obtain a CSF of an oblique path, or more specifically, a CSF of a 612-km skywave path similar to that of the on-air trials. To the best of my knowledge, the Doppler transformation technique has not yet been investigated in relation to an evaluation of HF modem performance. The result would encourage the use of the range-conversion techniques, both for frequency and Doppler frequency, for real time frequency management. Comparisons between range-converted ionograms and actual OI ionograms are presented.

The second component of this study is the investigation and implementation of channel simulation system which is based on the Vogler and Hoffmeyer wideband model. The model can represent a wider range of propagation conditions than those offered by the Watterson model. The propagation condition such as spread-F, which is typically observed at low latitudes, can be simulated and studied. The channel transfer function is generated and applied to the test HF modem waveforms.

Finally, the performance of two HF modem waveforms, Frequency Shift Keyed (FSK) and Frequency Modulated Continuous Wave (FMCW) or chirp waveforms, are evaluated using the simulated channel. The results are the approximated BER performance of HF modem waveforms under the channel conditions based on the range-converted to 612-km CSFs. The validation of the CSF-based BER estimation method is made using the performance of HF modems measured during the on-air trials at the time close to the VI Doppler ionogram sounding.

The proposed technique offers an alternative approach to HF channel simulators and could be implemented to assist real time frequency managements. Other types of modem waveforms could be applied to this technique. However due to certain proprietary software, information for implementing some modem waveforms was not available. The proposed technique has also proved to be very useful for simulating all types of ionospheric channel conditions either obtained from actual measurements or generated by models. The technique is not restricted to the equatorial regions and can be applied to mid and high latitudes.